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Comparison of the Gonadal Growth of Six Groups of Sea Urchins, *Strongylocentrotus intermedius*, Reared by Different Quantities of Laminaria in Polyethylene Net Cages on the Shallow Reef of Rumoi, Hokkaido

[95]

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(Hokkaido Wakkanai Fisheries Experimental Station)
Tomekichi USHIRO*3, Masashi YUKI, Akira EBISU*4 and Isao ISOZAKI
(Rumoi Southern Regional Fisheries Technology Dissemination Advisory Office)

Sea urchin fishery has as its production target the gonads of sea urchins, and the quantity as well as the goodness or poorness of quality of the gonads affect the productivity of the fishery. Also, depending on the fisheries cooperative association, there are those that regulate the catch according to shucked weight, in which case the gonadal quantity per individual sea urchin can be thought to be one of the important elements in terms of resource management as well.

Up to now, with the aim of improving the quantity and quality of the gonads of sea urchins, transplantation experiments and projects have been carried

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*1 Now at Cultivated Fisheries Coordination Centre
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*3 Now at Nemuro Regional Fisheries Technology Dissemination Advisory Office
*4 Now at Rumoi Northern Regional Fisheries Technology Dissemination Advisory Office

out selecting sites rich in feed kelp, and approximately 50% of the fisheries cooperative associations in Hokkaido are engaged in such projects.[1)-5)]

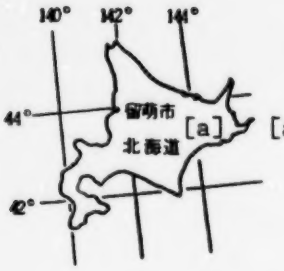
On the other hand, along the coast from the central to southern section of the Japan Sea off Hokkaido are many places with sparse growth of feed kelp, and the sea urchins in such waters are generally not only small in body growth but also low in gonadal quantity, lowering the productivity of the sea urchin fishery. To enhance the gonadal growth of such sea urchins low in economic value is thought to be an important matter from the aspect of effective utilization of resources as well.

The authors, at Rumoi which is one of such waters extremely sparse in feed kelp, gave cultivated kelp or natural narrow kelp to Strongylocentrotus intermedius small in gonadal quantity in an attempt to improve gonadal growth, and having obtained some information they are hereby reported.

Before getting into the main text, we should like to express our warm appreciation to Messrs. Masayuki YUKAWA and Tamotsu IZUMIYA of Rumoi Municipal Fisheries Department and to Mr. Tomiji HARADA of the Rumoi Fisheries Cooperative Association and all the members of the waterfront cooperatives for their tremendous cooperation in the course of carrying out the present experiment.

Materials and Method [96]

The Strongylocentrotus intermedius used in the experiment were collected on May 10, 1982 at a spot extremely sparse in kelp off Rumoi's Santomari waterfront in depths of 3-6 m. Dividing the specimens of 4-6 cm shell diameter into six groups of 200 individuals each, they were housed in breeding cages set on a flat beach at a depth of 0.8 m on this waterfront (Fig. 1; Table 1). The breeding cages were 3 x 2 x 1 (height) m in size, made by covering the sides of an iron-bar frame with Trical net (27 mm mesh) and the ceiling section with old fishnet (30 mm mesh). Inside were laid 2-3 layers of 30-50 cm boulders (Fig. 2).



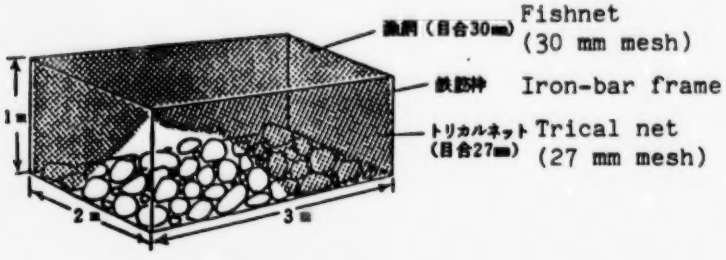
[a] Rumoi City, Hokkaido

第1図 試 験 地
Fig. 1. Experimentation site

Table 1. Shell diameter and total weight at experiment commencement time

[a]給餌量	[b] 殻 径 (mm) 平均値±標準偏差	[c] 全重量 (g) 平均値±標準偏差
[d]無給餌	49.8 ± 7.3	53.6 ± 21.8
2.5 kg	48.3 ± 6.5	48.5 ± 18.9
5	47.5 ± 5.7	46.0 ± 16.2
10	48.9 ± 6.4	48.4 ± 18.6
20	50.2 ± 6.2	56.9 ± 18.6
40	49.7 ± 7.9	55.9 ± 21.6

[a] Feeding rate
[b] Shell diameter (mm)
Mean ± standard deviation
[c] Total weight (g)
Mean ± standard deviation
[d] Unfed



第2図 飼育籠の模式図
Fig. 2. Sketch of breeding cage

Feed consisting of cultivated kelp and natural narrow kelp was supplied once roughly every ten days, continuing the breeding for 102 days from May 10 to August 20. The supplied feed quantity per trial was given at five different rates consisting of 2.5 kg, 5 kg, 10 kg, 20 kg, 40 kg, and including an unfed group the experiment was done with six groups.

On May 10 50 specimens collected at the same time as those used in the experiment, and on June 20, July 20, August 20 around 20 specimens from each of the six groups under breeding were taken, and the shell diameter, shell height, total weight, gonad weight, digestive tract content weight and shell weight were measured (unit: mm, g). Also on August 20 all the remaining specimens were [97] taken out and their shell diameter and weight measured.

In order to learn the amount of growth of the gonads, a gonadal index was determined by the following.

$$\text{Gonadal index} = \frac{\text{Gonad weight}}{\text{Total weight}} \times 100$$

Using the index values for June 20, July 20, August 20, a one-dimensional distribution scatter analysis was performed in each case, and then doing a comparison of the means among the six groups (F) by the method of least significant difference and a comparison of the means between the unfed group and each fed group (t') by a one-sided test, the matter of whether or not there were significant differences in the gonadal growth of the six groups was examined.[6)]

$$F = \frac{N(Xp - Xq)^2}{2V_R}$$

$$t' = \frac{|Xt - Xc|}{\sqrt{2V_R/N}}$$

Here, N is the sample number, Xp and Xq are the means for the respective groups, V_R is the error dispersion, Xt is the mean for each fed group and Xc is the mean for the unfed group.

The digestive tract content index and shell weight index were determined by the following.

$$\text{Digestive tract content index} = \frac{\text{Digestive tract content weight}}{\frac{(\text{Shell diameter})^2 \times (\text{Shell height})}{1000}} \times 100$$

$$\text{Shell weight index} = \frac{\text{Shell weight}}{\frac{(\text{Shell diameter})^2 \times (\text{Shell height})}{1000}} \times 100$$

Determining the difference between the supplied feed quantity and the residual feed quantity approximately ten days later, this was taken as the feed consumption volume including both the amount directly ingested by the Strongylocentrotus intermedius and the amount washed away by the feeding activity and such, whereby the consumption volume per day per individual was calculated.

The number of mortalities during the experimentation period was determined by subtracting the total numbers measured on June 20, July 20 and August 20 from the housed number.

The water temperature was measured by placing a Ryan Co.-made self-registering thermometer on the breeding cage.

Results

1) Water temperature

The variation in water temperature from June 2 to August 20 has been shown in Fig. 3. During the experimentation period it ranged between 15-28°C

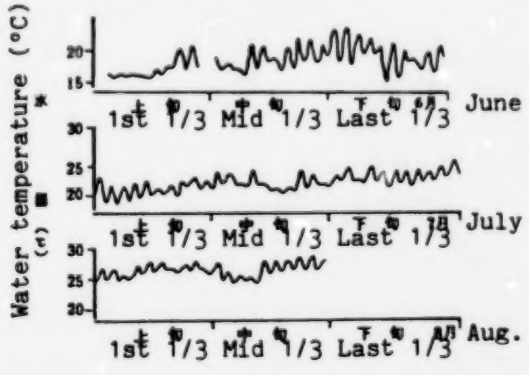


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Fig. 3. Water temperature variation at the experimentation site

in an upward trend. Nevertheless, because it was on a flat beach at a depth of around 0.8 m that the experiment was conducted, the water temperature variation was severe between day and night, clear skies and cloudy, etc., with swings in water temperature of as much as 7°C occurring in a day at times.

2) Feed consumption volume [98]

The feed consumption volume per day per individual Strongylocentrotus intermedius in the five fed groups has been shown in Fig. 4. The 2.5 kg fed group was in the 1.1-2.8 g range and the 5 kg fed group in the 2.1-7.8 g range, indicating a minutely increasing trend. The 10 kg fed group was in the 2.5-7.8 g range, with the variation from the middle third of July on becoming large.

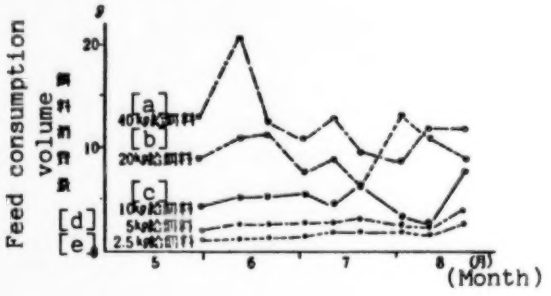

Fig. 4. Variation in feed consumption volume per day per individual Strongylocentrotus intermedius in the five fed groups

[a] 40 kg fed group
[b] 20 kg fed group
[c] 10 kg fed group
[d] 5 kg fed group
[e] 2.5 kg fed group

The 20 kg fed group was in the 6.2-13.0 g range and the 40 kg fed group in the 10.7-20.8 g range, with a decreasing trend from July on being discerned. Looking at it overall, the groups with the higher feed supplies tended to also have the higher consumption volumes.

3) Gonadal index

The variation in the gonadal index of the six groups of Strongylocentrotus intermedius has been shown in Fig. 5, while a comparison of the differences in

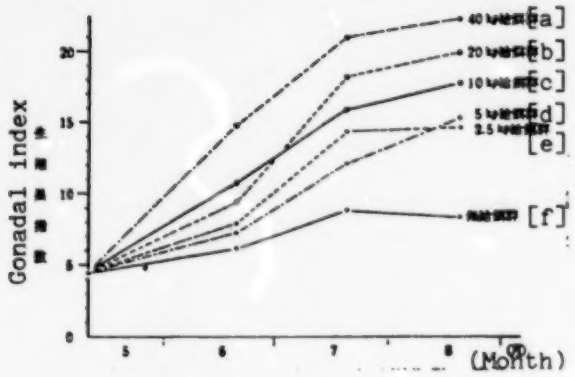

Fig. 5. Variation in gonadal index of the six groups of Strongylocentrotus intermedius

$$\text{Gonadal index} = \frac{\text{Gonad weight}}{\text{Total weight}} \times 100$$

[a] 40 kg fed group
[b] 20 kg fed group
[c] 10 kg fed group
[d] 5 kg fed group
[e] 2.5 kg fed group
[f] Unfed group

the means has been shown in Table 2. In every group the gonadal index increased along with the lapse of breeding time. What had been a mean of 4.38 in the gonadal index on May 10 when the experiment commenced became by June 20 41 days later 6.15 in the unfed group and 7.21-14.71 in the fed groups, with the dispersion ratio of the six groups being 10.83 and differences at the 0.01 significance level being discerned. Also, where differences in the means at the 0.01 or 0.05 [99] significance level could be discerned among the five fed groups relative to the unfed group was in the 10-40 kg fed groups, with that difference being marked particularly in the 10 kg and 40 kg fed groups. Among the fed groups themselves, the 10 kg and 40 kg fed groups revealed differences in the means at the 0.01 significance level relative to the three groups fed 5 kg or less and 20 kg. Apart from that, the 20 kg fed group revealed a difference at the 0.05 significance level relative to the 5 kg fed group. At this point in time the gonadal growth in the 10 kg and 40 kg fed groups was notable in comparison to the rest of the fed groups and the unfed group.

Table 2. Comparison of differences in means of gonadal index (* denotes difference discerned at 0.05 significance level, ** at 0.01 significance level)

[a] 1982年6月20日　分散比 10.83**

[b]給餌量	t'	F					
		0 kg	2.5	5	10	20	40
0 kg		—			**	*	**
2.5			—		**		**
5				—	**	*	**
10	**	**	**	**	—	**	
20		*		*	**	—	**
40	**	**	**	**		**	—

[c] 1982年7月20日　分散比 11.05**

[d]給餌量	t'	F					
		0	2.5	5	10	20	40
0 kg		—	**	*	**	**	**
2.5	**	**	—				**
5	*	*		—		**	**
10	**	**			—		**
20	**	**		**		—	
40	**	**	**	**	**		—

[e] 1982年8月20日　分散比 24.46**

[f]給餌量	t'	F					
		0	2.5	5	10	20	40
0 kg		—	**	**	**	**	**
2.5	**	**	—		**	**	**
5	**	**		—	*	**	**
10	**	**	**	*	—		**
20	**	**	**	**		—	
40	**	**	**	**	**		—

[Note] t': Comparison between unfed group and five fed groups
F: Comparison among six groups by the method of least significant difference

[a] June 20, 1982　　Dispersion ratio 10.83**
[b] Feeding rate
[c] July 20, 1982　　Dispersion ratio 11.05**
[d] Feeding rate
[e] August 20, 1982　　Dispersion ratio 24.46**
[f] Feeding rate

By July 20 71 days later the mean of the gonadal index of the six groups of Strongylocentrotus intermedius became 8.79 in the unfed group and 12.04-20.92 in the fed groups, with a dispersion ratio of 11.05 and differences at the 0.01

significance level being discerned. Each of the fed groups revealed a difference in the means either at the 0.01 or 0.05 significance level relative to the unfed group. Also, among the fed groups themselves, differences in the means at the 0.01 significance level were discerned in the 20 kg fed group relative to the 5 kg fed group and in the 40 kg fed group relative to the three groups fed 10 kg or less. By this point in time the difference in gonadal growth between the unfed group and the five fed groups had become notable, with the 20 kg and 40 kg fed groups in particular having marked growth in comparison to the rest of the groups. [100]

By August 20 102 days later the means of the gonadal growth of the six groups of Strongylocentrotus intermedius became 8.36 in the unfed group and 14.74-22.27 in the fed groups, with a dispersion ratio of 24.46 and differences at the 0.01 significance level being discerned. The five fed groups revealed differences in the means at the 0.01 significance level relative to the unfed group. Also, among the fed groups themselves, differences in the means at either the 0.01 or 0.05 significance level were discerned in the 10 kg and 20 kg fed groups relative to the two groups fed 5 kg or less and in the 40 kg fed group relative to the three groups fed 10 kg or less. From July 20 to August 20 as compared to before that, the amount of gonadal growth declined somewhat.

4) Number of mortalities

The number of mortalities among the six groups of Strongylocentrotus intermedius has been shown in Table 3. While the unfed group with 92 mortalities and the 2.5 kg fed group with 76 mortalities had comparatively many, the groups fed 5 kg or more had, with the exception of the 20 kg fed group's 67 mortalities, comparatively few at 30-40 mortalities. Looking at it overall, the groups with the higher feed supplies tended to have a lower number of mortalities.

Table 3. Number of Strongylocentrotus intermedius housed, measured and which died

[a]給餌量	[b]収容数 5月10日	[c]測定数 6月20日	7月20日	8月20日	[d]死亡数
[e]無給餌	200	20	21	67	92
2.5 kg	200	20	20	84	76
5	200	20	18	122	40
10	200	20	20	129	31
20	200	20	21	92	67
40	200	20	20	130	30

[a] Feeding rate
[b] Number housed
May 10
[c] Number measured
June 20 July 20 August 20
[d] Number of mortalities
[e] Unfed

5) Digestive tract content index and shell weight index

The digestive tract content index has been shown in Fig. 6 and the shell weight index in Fig. 7. While the digestive tract content index was comparatively large in the unfed group, collectively it exhibited a decreasing trend. The shell weight index as a whole exhibited an increasing trend. Both, however, in contrast to the gonadal index, gave no clear relationship with the feeding rate.

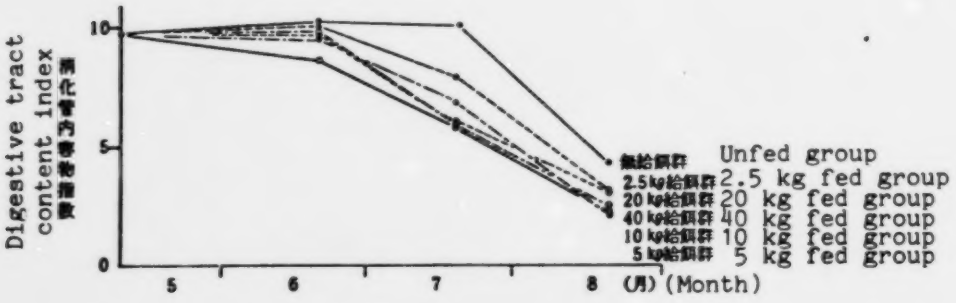

Fig. 6. Variation in digestive tract content index in the six groups of Strongylocentrotus intermedius

$$\text{Digestive tract content index} = \frac{\text{Digestive tract content weight}}{\frac{(\text{Shell diameter})^2 \times (\text{Shell height})}{1000}} \times 100$$

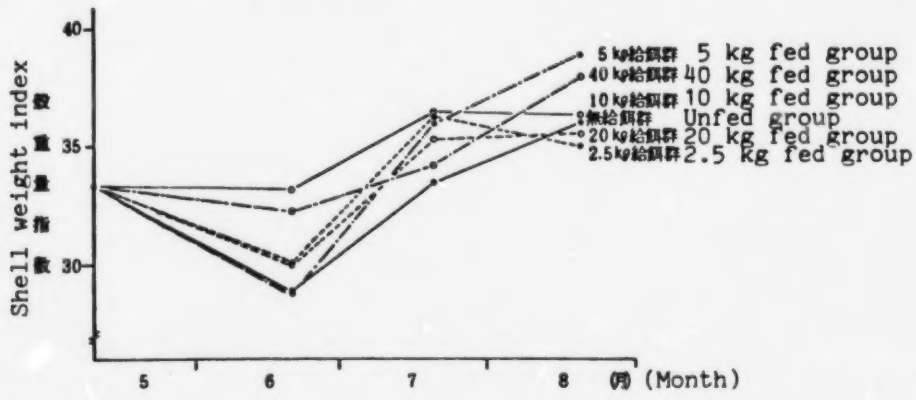

Fig. 7. Variation in shell weight index in the six groups of Strongylocentrotus intermedius

$$\text{Shell weight index} = \frac{\dfrac{\text{Shell weight}}{(\text{Shell diameter})^2 \times (\text{Shell height})}}{1000} \times 100$$

Discussion

The gonads of Echinoidea are, along with being an organ for reproduction, also a repository organ for nutriments. Food that has been ingested is, after being absorbed in the digestive tract, stored in the gonads as nutriment.[7] For this reason, food is an extremely important factor for the growth of the gonads, and the fact that the type and quantity of food are related to the quantity and quality of the gonads of Echinoidea is well known from ecological investigations at various places heretofore.

According to the results of experimentation conducted on this occasion, there is a close relationship between the amount of gonadal growth in Strongylocentrotus intermedius and the feed consumption volume, with the amount of increase in the index and the cumulative feed consumption regressing to the following equation (Fig. 8).

$$Y = -13.29 + \ln X^{3.615} \qquad [101]$$

Here, Y denotes the cumulative feed consumption volume per individual, X denotes the amount of increase in the index obtained by subtracting the index for the

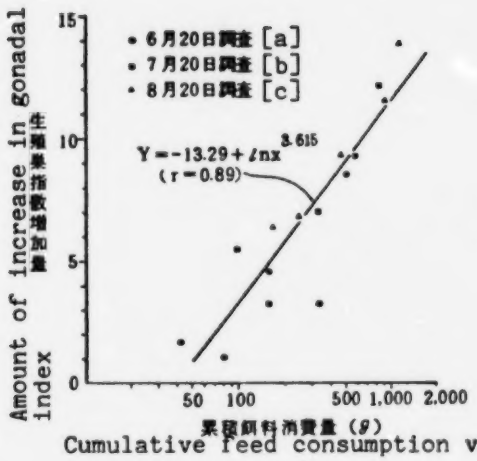

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Fig. 8. Relationship between amount of increase in gonadal index and cumulative feed consumption volume per individual Strongylocentrotus intermedius

[a] June 20 examination
[b] July 20 examination
[c] August 20 examination

unfed group from the index of each of the fed groups. In this case the correlation coefficient was 0.89 and the 99% confidence intervalwas 0.58-0.98. Also, the correlation coefficients for the 41st day, 71st day and 102nd day were 0.78, 0.89 and 0.98, respectively, and the longer the breeding period becomes the clearer the feeding effect could be surmised to become.

The amount of increase per day in the gonadal index of Strongylocentrotus intermedius during the experimentation period was 0.026-0.209 until June 20, 0.073-0.273 from June 20 until July 20 and 0.054-0.147 from July 20 until [102] August 20, so the gonadal growth by the middle third of July can be surmised to have been pronounced.

The digestive tract content lessened in the fed groups from the latter third of June on and in the unfed group from the latter third of July on, and with the feed consumption volume also exhibiting a decreasing trend from July on in both the 20 kg and 40 kg fed groups, the feeding activity is thought to have weakened. This, as pointed out by FUJI,[8] is believed to be the effect of gonadal growth.

In the experiment on this occasion, it was found that by feeding Strongylocentrotus intermedius low in gonadal quantity at the growth stage, it is possible to enhance the growth of the gonads to a maximum of around five times in about two months, and given a consumption of approximately 1 kg of Laminaria per individual the gonadal index can be expected to increase approximately twelvefold. However, because in the present experiment the difference between the supplied feed quantity and residual feed quantity was taken as the consumption volume, a decrement due also to being washed away and not just ingestion is thought to be included. For this reason, in comparison with the ingestion volume obtained in the indoor experiment by FUJI[8] (approximately 3 g of kelp per day per individual), a fairly large value is surmised to have resulted. Also, while many mortalities were seen during the breeding period of 102 days, these are thought to be related to a rise in water temperature and lack of seawater exchange but no details are known. In the future there is a need to examine efficient feeding methods, including feeding in ordinary fishing grounds.

Summary

Breeding Strongylocentrotus intermedius in cages set in the sea off Santomari, Rumoi City, from May 10 to August 20, 1982, the growth of the gonads was observed. Housing 200 individuals each in six cages, besides an unfed group, 2.5 kg, 5 kg, 10 kg, 20 kg and 40 kg of Laminaria were fed once roughly every ten days. Gonadal growth continued from the commencement of the experiment until the middle third of July, and the groups with the greater feed supplies also tended to have more growth, becoming as much as approximately five times at the maximum. Also, the cumulative feed consumption volume per individual and the gonadal index indicated a positive correlation, yielding this regression equation:

$$Y = -13.29 + \ln X^{3.615}$$

The number of mortalities during the period was 30-92 individuals, tending to be fewer among the groups with the greater feed supplies.

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